

An Experimental DRM Receiver

DDS meets DRM

By B. Kainka

Did you know that the BBC transmits digitally on shortwave and medium wave? The only trouble is DRM (Digital Radio Mondiale) radios are not widely available yet. This article describes how the *Elektor Electronics* DDS RF Signal Generator can be used together with a little extra hardware and some software to receive these high quality stereo broadcasts on a PC or Notebook.

The new digital broadcasting standard for short wave radio (and all bands below 30 MHz) is known as Digital Radio Mondiale (DRM). The system requires a high specification for the receiver but if you've already built the Direct Digital Synthesiser (DDS) frequency generator described in the October issue of *Elektor Electronics* the rest of the receiver design is simple. An alternative receiver design is also included in this article that does not need the DDS generator.

Take a look at the DRM transmission times and frequencies listed in English at www.drm-dx.de. DRM transmissions can be picked up on a normal AM radio but all you can hear from the speaker is a high level of white noise as you tune into the signal. The DRM signal actually consists of a large number of QAM carriers that together produce a digital data stream representing the program content. Each carrier can have 64 states so the phase constant of the receive oscillator is very important to ensure reliable reception. See [1] for a more detailed background of the DRM standard. The smallest amount of phase noise in the mixer oscillator results in a degraded or unreadable input signal. This is where the DDS signal generator comes into its own; it has very low phase noise similar to a quartz oscillator and is also very accurately adjustable and stable.

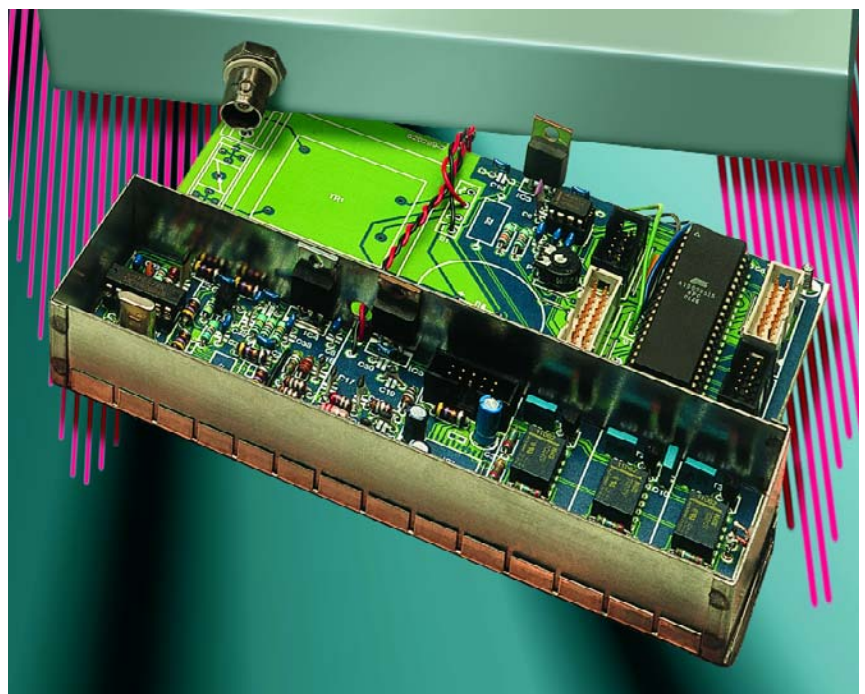


Figure 1. The Elektor Electronics DDS Generator.

Conventional oscillators using tuning capacitors or PLLs are not as suitable for this application. If you start off with the DDS generator the

rest of the receiver design becomes very simple. Even basic receivers will produce good results when a good quality oscillator is available.

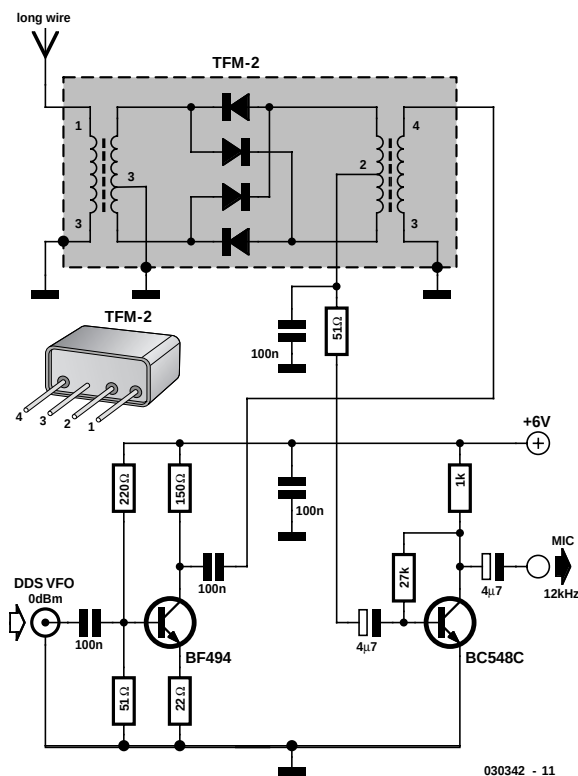


Figure 2. The 50 Ω Direct mixer.

The receiver design is very simple; the incoming RF signal is mixed down with a local oscillator (the DDS generator) to produce a 12 KHz signal, this is fed directly into the sound card input of a PC. Software now does all the tricky stuff like decoding the digital signal and converting it into an analogue signal before it is output to the PC's speakers.

The direct mixer

The direct mixer is one of the most simple receiver concepts. The incoming HF radio signal is mixed down to produce a 12 KHz baseband signal in one single step. The local oscillator must therefore run at a frequency equal to the received signal plus or minus 12 KHz.

One disadvantage of the direct mixer is that it does not offer any rejection of the image frequency this means that the receiver is also sensitive to a signal 24 KHz away from the desired signal. If you are lucky there will be no other transmitters sending on this frequency. This 'feature' does give you two tuning points to receive the same signal for example if you wanted to tune into

the BBC World Service DRM transmissions sent out from the relay station in Sackville, Canada on 9795 KHz you could set the local oscillator frequency to either 9807 KHz or 9783 KHz. If another strong station is sending on 9771 KHz the signal will be mixed at the same frequency as the wanted signal (9783 KHz – 9771 KHz = 12 KHz) so in this case it is better to tune to the image frequency of 9807 KHz. The 'jamming' signal now produce a 36 KHz output signal that will be removed by the filter fitted to the input of the A/D converter in the sound card.

The DDS generator designed by G. Baars (Figure 1) and published in the October 2003 issue can produce both amplitude and frequency modulated output signal but these are not required for this application. The important features of this generator are the frequency range up to 30 MHz and the simple method of selecting the frequency using a keypad or rotary encoder control knob. The output signal level is adjustable up to 0 dBm (224 mV into 50 Ω) this ensures that the mixer can be driven at its optimum input signal level.

First tests were carried out using a diode ring mixer type TDM2 from Mini Circuits (www.minicircuits.com). A BF494 transistor is used as a wide band amplifier to raise the signal level from the DDS oscillator to around 7 dBm. A low noise transistor type BF548C is used as an AF amplifier at the output from the mixer to ensure that there is sufficient signal to drive the microphone input of the sound card. The mixer impedance of around 50 Ω ensures that it can handle large input signals.

The antenna can be just a long wire sited outdoors as high up as practical but if space is at a premium then an antenna length of between one and three metres should be sufficient.

Unlike most RF projects this design does not contain any tuned circuits so the component layout is relatively uncritical. Figure 3 shows the prototype circuit built on a small piece of perforated strip board.

Decoder

Once you have attached an aerial to the receiver, switched on the DDS generator and connected the output of the simple receiver to the microphone input of your soundcard, the DRM Software Radio program from Fraunhofer-IIS can be started. This program is available online from the home page www.drmtx.org and costs around 60 Euros (approx £ 45). An open source program has also been developed for DRM reception and we will take a closer look at this towards the end of the article.

The tuning example given earlier indicates the importance of selecting the correct frequency to avoid interfering stations, if you need to tune to the image frequency the

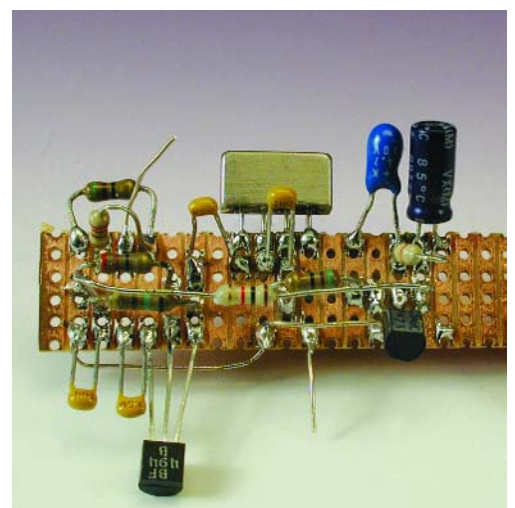


Figure 3. The prototype receiver.

recovered baseband signal will have its frequency spectrum mirrored or inverted so its important to be able to put the signal spectrum back the right way round. **Figure 4** shows the software option for correcting this inversion.

A window in the *DRM Software Radio* display shows the 10 kHz wide frequency spectrum of the received signal, this comes in handy if you are tuning manually to ensure that the flat-topped DRM signal is centred in the display. The display also has several 'virtual LEDs'. When a DRM signal is detected the first of these LEDs will light after a few seconds to indicate that the software has synchronised to the incoming signal next the data LED comes on and the station name together with other information such as the signal data rate and stereo/mono mode is displayed on the PC. If you are lucky and the signal strength is sufficient the third LED will illuminate after a few more seconds and then hey presto... high fidelity sound comes flooding from the speakers! All this from a short wave signal, it's certainly a long way from the fading, garbled, erratic sound that we are used to.

As with all short wave reception, the signal relies on reflection from the ionosphere to achieve its long range and all this digital technology does not protect the signal from the uncertainties of this propagation path so that distant weak stations will still be subject to audio dropouts.

The signal to noise ratio (S/NR) is displayed in real time, a figure of 25 dB is a very good value and even expensive short wave receivers would have trouble achieving this. The direct mixer produces good results as long as you are aware of the drawbacks of no image rejection and the absence of an automatic level control (ALC) of the received signal. On top of this it also requires a fairly long aerial to give a good input signal level.

The simple direct mixer has very wide band characteristics and does not require any input filter selection so that tuning across the entire short wave band is accomplished by simply changing the local oscillator frequency. In Europe the BBC World Service is currently transmitting DRM coded programs using transmitters at Orfordness (1296 kHz) and Rampisham (various SW frequencies). In addition Dutch and German World Service transmitters also broadcast English language programs for example Deutsche Welle on 15440 kHz in the mornings. When tuning into the broadcasts always try both frequencies to find optimum reception but it's often the case that strong stations are transmitting on both these frequencies and the signal gets swamped.

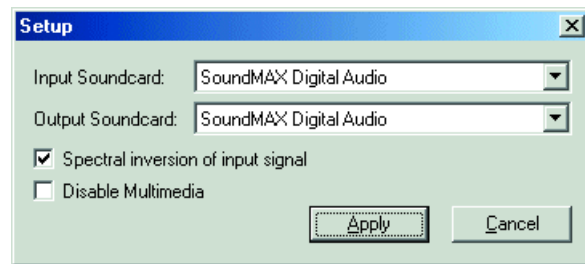


Figure 4. The program allows for spectral inversion of the received signal.

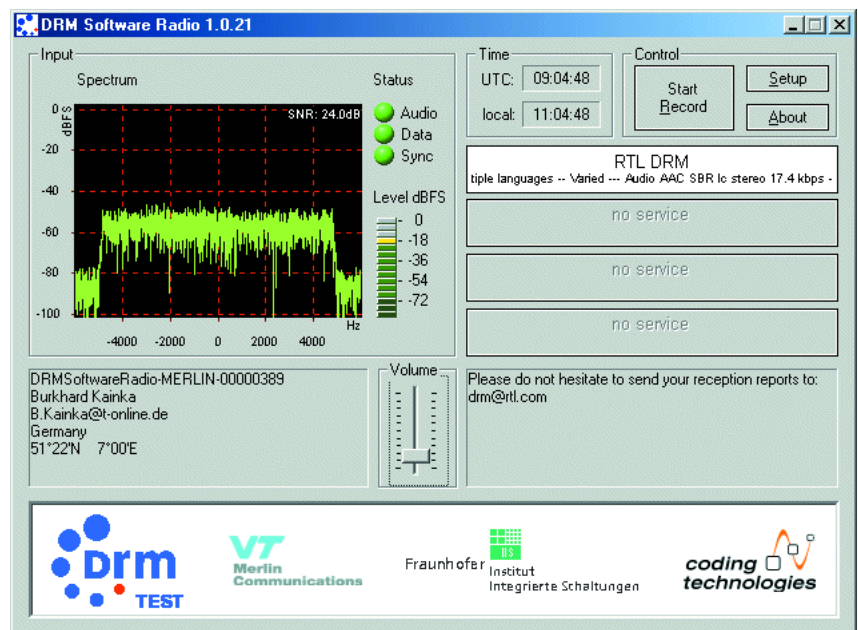


Figure 5. Radio Luxembourg reception.

Homebrew diode ring mixer

The basic goal of this article was to build a DRM receiver and this has been achieved but the diode ring mixer used in the receiver design is quite an expensive component. Alternatives like the popular IE500 can also be used but you may also be interested in having a go at building your own mixer from discrete components.

A homebrew diode ring mixer can be built with four type BAR28 Schottky diodes and two wide band transformers. Each RF transformer is wound on an Amidon T37-2 (red) toroidal core with an A_L value of 40 nH/n². Three lengths of 0.3 mm enamelled copper wire are wound together ten times through the core to produce the trifilar windings. Ten turns produces an inductance of

4 μ H giving the mixer an impedance of 50 Ω at 2 MHz. The wideband characteristic ensures that the entire short wave band can be received.

The ends of the windings can now be tinned and an ohmmeter used to identify each end of the windings. Two of the windings are now connected in series to form the two centre tapped windings connected to the diodes. The remaining winding on each core is used for the signal input (aerial) connection and the oscillator input. The four diodes can now be soldered in place to produce the finished mixer.

The homebrew mixer can best be tested with an oscilloscope. The upper trace shown in **Figure 8** shows the input on the secondary side of the oscillator transformer and the lower trace is the RF input. The oscillator signal shows limiting as the diodes are driven

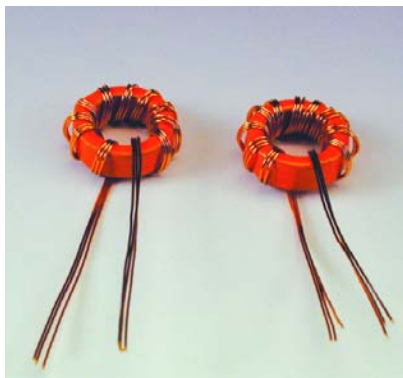


Figure 6. Winding the toroidal transformers.

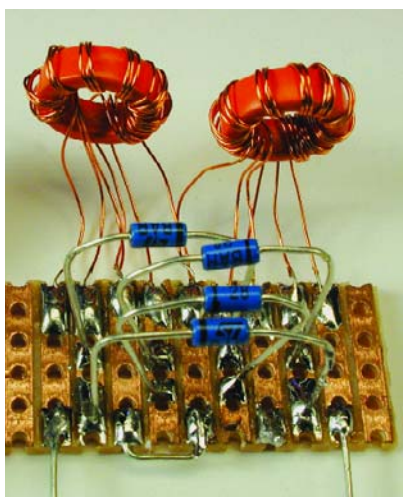


Figure 7. The trifilar wound ring mixer.

into conduction. At the RF input there is practically no evidence of the oscillator input signal, indicating that the mixer has good carrier suppression.

With an aerial attached and the homebrew mixer fitted in place of the commercial unit the receiver was tested again and worked just as well, but that's not to say that our mixer has a specification equivalent to the commercial unit but just that

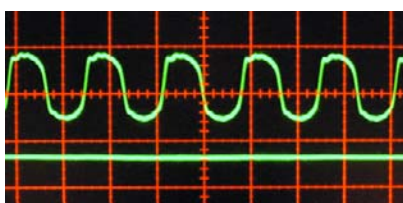


Figure 8. Oscillator drive signal and carrier suppression measurement.

it is more than adequate for receiving DRM broadcasts.

Direct mixing with an NE612

A ring mixer is a relatively simple device and introduces a certain amount of attenuation in the signal path whereas an alternative type called an 'integrated balanced mixer' produces some mixing gain and also does not require a broadband transformer so altogether this device can offer a more economical solution.

A very popular low cost integrated mixer is the NE612, this device contains an internal oscillator and a fully symmetric mixer. An external oscillator with an output signal level between 200 mV_{pp} and 300 mV_{pp} can also be connected to pin 6. During tests with the *Elektor Electronics* DDS generator the optimum signal level was set to 250 mV_{pp}.

The receiver circuit is shown in **Figure 9**. A long wire antenna is used without any input selector. A small fixed value inductor is used at the input and this circuit can receive DRM signals with a S/NR of 20 dB maximum. The performance of this design is not as good as the diode mixer when receiving strong signals because it can be more easily over-driven which produces intermodulation distortion and corruption of the DRM signal. The advantages of the integrated mixer are its signal gain and increased sensitivity. This type is therefore better than the diode mixer if you are using a short antenna and are only receiving low-level input signals.

A manually tuned set

Would it be possible to build a DRM receiver without using the DDS signal generator? Well, in this application the DDS is used as a simple signal source so it would be possible to substitute an equivalent device like a manually tuned free running oscillator with a capacitor or diode for tuning but the oscillator needs to have very good stability and low phase noise. *DRM Software Radio* can tolerate a frequency offset of up to 500 Hz from 12 kHz. This degree of resolution is possible if bandsread

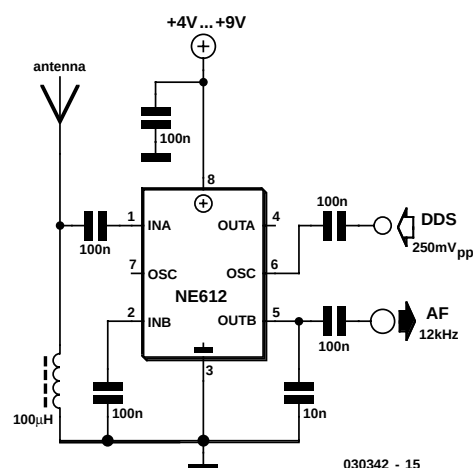


Figure 9. External tuning with a DDS generator.

tuning is used.

There are at least four frequencies in the 49-metre band used for transmitting DRM signals. **Figure 10** shows the circuit of a manually tuned receiver circuit that can be used on this band. The NE612 has an internal oscillator and requires an external adjustable tuned circuit. The oscillator has good frequency stability and a low phase noise and the coupled input filter gives effective rejection of out-of-band signals.

The oscillator input circuit connected to pin 7 of the NE612 is designed to give band-spread tuning over the 49-metre band. The coil consists of 20 turns on a 8 mm coil former and adjustment of the ferrite core gives a tuning range from 6 MHz to 7 MHz while a triple ganged air-spaced VHF tuning capacitor is used for fine-tuning. The coil in the antenna input circuit uses the same size former but this time the 20 turns is tapped at 5 turns and connected to pin 1 of the NE612. This coil is

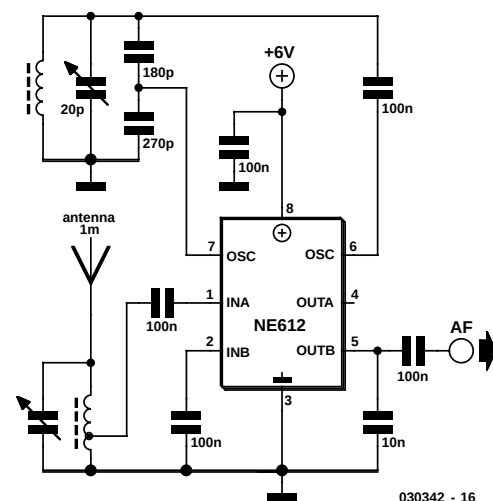


Figure 10. An integrated direct mixer.

not at all critical and you can experiment by connecting say a 120 pF fixed capacitor across the windings.

For testing the triple-ganged VHF tuning capacitor (salvaged from an old VHF tuner) was fitted into a screened enclosure for shielding and polystyrene capacitors were used throughout. The resulting circuit proved to be quite stable and remained on-station for many hours without adjustment.

The audio output signal level from pin 5 is suitable for direct connection to a line input and is also not too large for connecting to a microphone input. This receiver has been used to listen to DRM broadcasts on the 49 metre band and like any other direct-mixer it does not have image rejection so you need a certain amount of luck to be able to listen for any length of time without interference from other stations.

The receiver designs are a good first step in listening in to DRM signals but a different, more complicated receiver such as a superhet would solve the problem of image frequency and also give an improved SNR so that more distant stations could be picked-up.

Free software

In addition to the commercially available DRM software already mentioned there is also a similar open-source program called DREAM which was developed by Volker Fischer and Alexander Kurpiers of the Institute for Communications Technology at Darmstadt University. The project DREAM can be found at:

www.tu-darmstadt.de/fb/et/uet/fquet/mitarbeiter/vf/DRM/DRM.html

All the source files can be downloaded from <http://sourceforge.net/projects/drm/>. The files are intended as a resource for software developers interested in the details of the decoder function. The authors have not made the compiled executable file available because some of software components are not intended for free distribution.

Those of you who are not interested in compiling the source files (or do not have a C++ engine installed) may be lucky and find a compiled version available for download from the Internet. Many colleges and universities use the original program and there are a number of sites that have the DREAM program to download. Try entering the keyword DREAM.EXE into a search engine and you will no doubt find several hits. These sites are not entirely reliable and cannot be recommended; one offered the source code along with separate DLL files whilst another had the complete program compiled in one file.

In principle the DREAM software does the

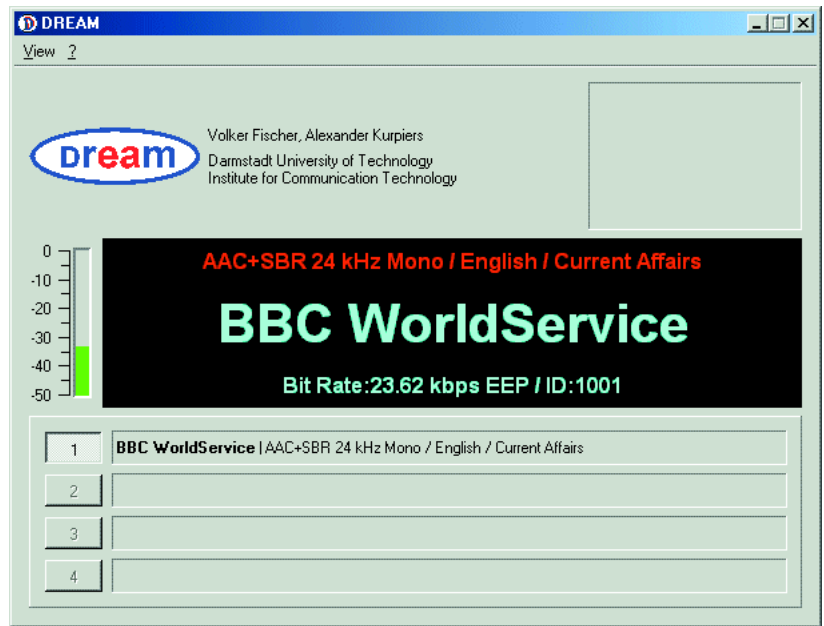


Figure 11. The DREAM program.

same job as the *DRM Software Radio* but has no multimedia possibilities. However it can handle different types of DRM transmissions including signals up to 20 kHz bandwidth and channel bundling. It also provides a good user dialogue with numerous options and display indicators. An advantage of the software is that the IF frequency need not be exactly 12 KHz, a wider range can be selected and this is ideal for homebrew receivers where the range may be limited or when an existing radio is converted for DRM reception.

The DREAM software (Figure 11) is more processor-hungry than the Fraunhofer-IIS software — in tests with a 1.3 GHz Pentium machine the *DRM Software Radio* ran without problems in the background while other applications such as Word, a graphics program and an Internet browser were used. DREAM on the

other hand is a bit of a loner and would only work happily when no other programs (including firewalls and virus alerts) were running. Calling up other applications would inevitably lead to a crash on our system set-up.

As a footnote the author has plans for a DRM receiver that may see the light of day as an *Elektor Electronics* project sometime in the future...

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Literature:

- [1] H. Weber,
Digital Radio Mondiale,
Elektor Electronics December 2002.

Weblinks:

- www.drm.org (general DRM info)
- www.drmrx.org (DRM test project)
- www.rnw.nl/realradio/html/drm.html (Radio Netherlands DRM Site)
- www.CodingTechnologies.com (DRM receivers)
- www.iis.fraunhofer.de/dab/products/drmreceiver/index.html (FhG DRM Software Radio)